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Review of the doctoral dissertation

"Effects of re-usable organic materials on transformation of soil organic matter to improve selected soil properties and functions"

Author: Collins Amoah-Antwi

Supervisor: prof. dr hab. inż. Jolanta Kwiatkowska-Malina

Auxiliary Supervisor: dr hab. inż. Ewa Szara

1. Formal and legal basis

The legal basis for conducting the doctoral procedure is Act of March 14th, 2003 on academic degrees and scientific title as well as degree and title in the field of art (Ustawa z dnia 14 marca 2003 r. o stopniach naukowych i tytule naukowym oraz o stopniach i tytule w zakresie sztuki – Dz.U. 2003 r. nr 65 poz. 595 z późn. zm.). This review has been prepared in response to a letter PW.IR.17.2022 of July 27th 2022, signed by dr hab. inż Łukasz Uzarowicz, prof. SGGW, Chairman of the Agriculture and Horticulture Discipline Council, Warsaw University of Life Sciences.

2. General characteristics of the dissertation

The doctoral dissertation presented for review is assessing the effects of exogenous organic matter (biochar, brown coal waste) application on selected properties of the investigated soil (pH, CEC, SSA, TOC content) as well as their functions (heavy metal remediation, humic substances transformation, nutrient cycling and crop productivity). Soil organic matter plays a crucial role in carbon capture and storage. Overall, soil management and utilization should result in maintain soil quality, fertility and productivity especially as stocks of soil organic carbon have declined in many agricultural systems all over the world. In the last decades there has been a growing interest in the use of alternative fertilizers such as brown coal, biochar, composts produced from segregated biodegradable waste or biomass, as well as other organic

amendments, in agricultural and horticultural production. Soil organic amendments are a good source of stable organic carbon and, due to the presence of good-quality nutrients, can be efficiently used to improve the balance of organic matter, enhance carbon sequestration and stimulate activity of soil biodiversity. Most of the soil organic carbon, about 70%, occurs as humic substances (HS), whose properties can vary depending on environmental, natural factors – e.g. soil properties, plant species, climate as well as anthropogenic factors, such as type of management. Humic substances (both humic and fulvic acids), have been used to study the properties and function of soil organic matter for hundreds of years. HS, as a significant part of SOM, are universally recognized as the most reactive soil components maintaining the soil fertility and productivity status and are involved in most physical, chemical and biological processes within the soil environment. Using advanced instrumental analysis, like ^{13}C NMR, FTIR and UV-VIS spectroscopy, it is possible to describe the detailed chemical properties of humic substances and follow the direction of humification.

From this point of view, I consider the subject of the doctoral dissertation to be topical and of a great importance for further improvement of the C budget in soils.

In the doctoral dissertation presented for review Mr Collins Amoah-Antwi rightly assumed that various sources of exogeneous organic matter affect the dynamics of SOM transformation, increase SOM content and may be efficient for immobilizing soil contaminants. Furthermore, Author assumed that structural characteristics of humic acids isolated from different soils under different organic fertilization regime can provide data for the organic matter changes as well as the potential effects on soil functions.

To confirm these hypotheses a field-scale and laboratory pot incubation experiments were designed. In the literature, there is a lot of information on the effect of organic fertilization on the properties of SOM, however, there are only few publications characterizing the effect of brown coal waste and biochar formed from thermo-chemical transformation of reusable biomass (via coalification and pyrolysis respectively) on the quality of organic matter. A positive result of the dissertation would enable a significant improvement in the quality of organic matter studies which is the key to the further management of agricultural soils towards stabilization and even increasing the C budget in the ecosystems.

The dissertation is clearly structured, is written in English with an abstract in English and Polish. It contains eight chapters. Chapter 8 is entitled Annex and is available only in electronic version of the dissertation, although the Table of content of the printed version contains page

numbers and subsections. **In my opinion printed and electronic versions should be identical or information about the availability of Chapter 8 in electronic version only should be placed in the Table of content, at least.**

Throughout his dissertation Mr Collins Amoah-Antwi covers a broad range of aspects of organic amendments, types and efficacy of their application. The dissertation introduction in the first chapter provides general information about soil organic matter function and factors determining its transformation as well as alternative organic amendments. This chapter contain also clearly presented main and specific research hypotheses. Chapter 2 deals with scientific background of the types and efficacy of organic amendments with particular attention to biochar and brown coal waste characteristics and the effect of their application and on soil properties. In Chapter 3 Author describes experimental studies, both pot and field trials as well as methods used – which I consider correctly selected. Chapters 4 and 5 describes main findings and conclusions with some recommendation for future work. Properly selected references have been included in Chapter 6.

The main part of the dissertation is Chapter 7 containing three, peer-reviewed thematically related articles, published in 2020 – 2022 in scientific journals distinguished in Journal Citation Reports:

1. Amoah-Antwi C., Kwiatkowska-Malina J., Szara E., Thornton S., Fenton O., Malina G. 2020. Efficacy of woodchip biochar and brown coal waste as stable sorbents for abatement of bioavailable cadmium, lead and zinc in soil. Water Air Soil Pollut, 231(10), 1-17. IF 2.520 (70 ministerial points)
2. Amoah-Antwi C., Kwiatkowska-Malina J., Fenton O., Szara E., Thornton S., Malina G. 2021. Holistic assessment of biochar and brown coal waste as organic amendments in sustainable environmental and agricultural applications. Water Air Soil Pollut, 232 (3), 1-25. IF 2.520 (70 ministerial points)
3. Amoah-Antwi C., Kwiatkowska-Malina J., Thornton S., Fenton O., Szara E., Malina G. 2022. Assessing factors controlling structural changes of humic acids in soils amended with organic materials to improve soil functionality. Agronomy, 12(2), 283 IF 3.417 (100 ministerial points)

In all the papers the PhD student is the first Author and according to the attached statements, he is also the Author with the highest contribution (55% in each paper). The statements of the

co-authors were attached to the first and second publication, in the third one - only the statement of the main author was attached.

Results from the pot experiment described in publication 1 have proved that brown coal waste and biochar produced from conifer wood chips via low-temperature flash pyrolysis are an excellent sorbents and along with their high soil stability make them good materials for amelioration of soils contaminated with heavy metals. These findings are very promising and provides insights to the broad applicability of both organic amendments.

Results from 3-years multicropping field experiment with application of biochar and brown coal wastes as organic amendments, described in the article no. 2 indicated that biochar and brown coal waste application have longer-lasting soil quality benefits, lower pollution and sustainability indices compare to the farmyard manure application. The great advantage of this article is the compilation of the own, field experiment data with data taken from the literature. This allowed for a holistic approach to the assessment of biochar and brown coal waste as an organic alternative amendments.

Publication no.3 is more specific focused on the on direction of soil organic matter transformation as the result of biochar and brown coal waste application. Study sites were located in Germany (clayey silt), Austria (silt loam), and two sites in Poland (both soils - loamy sand). Humic acids were extracted according modified method that has been found as an acceptable and satisfactory for most soil types by the International Humic Substances Society.

Results of the molecular analysis of extracted humic acids indicate pedoclimatic factors that affect transformation of organic matter as well as age of soil organic matter and frequency of amendment. Biochar with the highest content of aromatic compounds (compare to brown coal waste and farmyard manure) increased the aromaticity of isolated humic acids. Higher aromaticity of soil humic acids improves soil functionality. More aromatic humic acids play a crucial role in many soil processes, weathering, metal binding and organic matter stabilization, formation and stabilization of soil aggregates what is particularly important as they affect diminish erosion processes.

I have the following comments and requests for clarification:

1. Don’t you think that very high C/N ratio of biochar and brown coal waste (94,9 and 82,6 respectively) would affect decrease of organic matter decomposition thus negatively affect humification processes as well as nitrogen availability for plants?

Despite the proven positive effect of both organic amendment on the fungal community (as is given in the Annex) don't you afraid of negative influence of both amendment on microbial population that enhance transformation of organic matter?

2. Elemental compostion of humic acids presents only C and N in their molecules, why H and O were skipped? Atomic ratio e.g. H/C or O/C or degree of internal oxidation could help to characterize structural properties of humic acids.
3. What was the ash content in the isolated humic acids and whether it was considered during C and N determination?
4. Comment: In the presented results almost no effect from the humic acids yields between sandy soils and silty and loamy soils was observed. I suspect that this situation was caused by very short extraction time using alkali solution (only 24 hours). To assess the quantity of humic substances this procedure should be repeated for each sample until the supernatant turned slightly yellowish, suggesting that HA had been exhaustively extracted.
5. During alkali extraction from soils with clay minerals mineral colloids appear in the supernatant – it affects higher ash content of HA. If/how did you solve this problem?
6. Comment: In Chapter 5 of the doctoral thesis as well as in publication 3 there is a confusing statement: "BIO which is rich in humified OM.." Humification is a natural process of organic matter transformation that is subjected to microbial degradation followed by condensation. "Humified organic matter" means relatively stabilized organic compounds in soil, sediments or water, resulted from plants and animals residues transformed through interactions with microorganisms and minerals. More specific, organic matter with high content of humic substances – mainly mature, aromatic in character humic acids, with CHA/CFA >1. Biochar is a carbonaceous material formed by pyrolysis of biomass under low oxygen conditions, thus cannot be rich in "humified organic matter". Maybe try to use some other term...

Summarizing, the research presented in the dissertation produced original and significant scientific results. I consider the results to be highly important. This is partially due to the fact that all publications have been peer-reviewed and deemed original research. I am very impressed by the amount of research and analysis carried out by Mr Collins Amoah-Antwi. The dissertation is not only of a high scientific value but important is its practical application

value as well. The work showed the Author's competence in the field of soil science and agricultural researches, the correct approach in the application of research methods as well as interpretation of the results.

I rate the presented dissertation very highly. It is the next step in the process of improving the quality of soil environment and agricultural ecosystems. The subject of the work is in the discipline agriculture and horticulture. Mr Collins Amoah-Antwi has demonstrated excellent knowledge of conducting scientific research. The candidate provided an original solution of a relevant scientific problem. In my opinion, the doctoral dissertation fulfils the requirements for a doctoral degree under the March 14th, 2003 on academic degrees and scientific title as well as degree and title in the field of art (Ustawa z dnia 14 marca 2003 r. o stopniach naukowych i tytule naukowym oraz o stopniach i tytule w zakresie sztuki – Dz.U. 2003 r. nr 65 poz. 595 z późn. zm.). Thus, the final conclusion for evaluation of the thesis is:

Positive (sufficient) <u>with honors (outstanding)</u> - I recommend the dissertation for an award.

Elżbieta Jamroz